SUGGESTIONS FOR TAKING MEASUREMENTS

TIME

The times that are required to work out the problems can easily be measured by using a watch with a second hand or a digital watch with a stop watch mode. When measuring the period of a ride that involves harmonic or circular motion, measure the time for several repetitions of the motion. This will give a better estimate of the period of motion than just measuring one repetition. You may want to measure the time two or three times and then average them.

DISTANCE

Since you cannot interfere with the normal operation of the rides, you will not be able to directly measure heights, diameters, etc. Most of the distances can be measured remotely using the following methods. They will give you a reasonable estimate. Try to keep consistent units, i.e. meters, centimeters, etc., to make calculations easier.

Pacing: Determine the length of your stride by walking at your normal rate over a measured distance. Divide the distance by the number of steps and you can get the average distance per step. Knowing this, you can pace off horizontal distances.

My pace = ____________ m

Ride structure: Distance estimates can be made by noting regularities int he structure of the ride. For example, tracks may have regularly spaced cross-members as shown in Figure a. The distance d can be estimated, and by counting the number of cross members, distances along the track can be determined. This method can be used for both vertical and horizontal distances.

Track

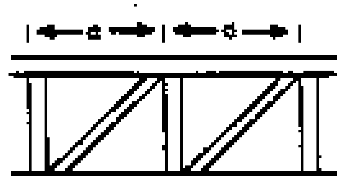


Figure a

Triangulations: For measuring height by triangulation, a sextant such as that is shown in Figure b can be constructed.

Practice this with the school flagpole before you come to Six Flags Great America.

Suppose the heights h_T of the American Eagle must be determined.

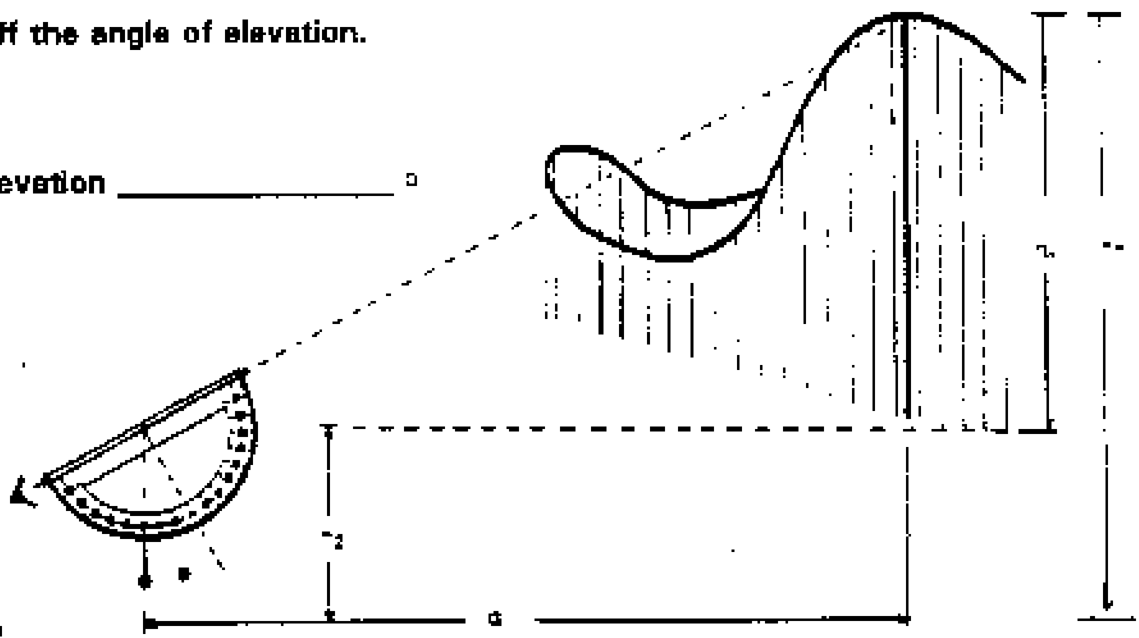
1. Measure the distance between you and the ride. You can pace off the distance.

2. Measure the height of the sextant above the ground.
   Sextant heights h_2: h_2 = ____________ m

3. Take a sighting at the highest point of the ride.

4. Read off the angle of elevation.

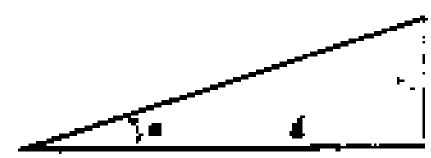
angle of elevation ________________ °



Then since

$h_1/d = \tan Ø$

$h_1 = d(\tan Ø)$



5. Look up the tangent value for the angle measured or use your scientific calculator:
   tangent value:

ANGLE	TANGENT	ANGLE	TANGENT	ANGLE	TANGENT
0°	.00	35°	.70	65°	2.14
5°	.09	40°	.84	70°	2.75
10°	.18	45°	1.00	75°	3.73
15°	.27	50°	1.19	80°	5.67
20°	.36	55°	1.43	85°	11.43
25°	.47	60°	1.73	90°	57.29
30°	.58				

6. Multiply this tangent value by the distance from ride: h_1 = __ m

7. Add this project to the height of the string hole: h_2 = __ m

This number is the height of the ride. h_T = __ m

Other: There are other ways to measure distance. If you can think of one, use it. For example, a similar but more complex triangulation could be used. If you can't measure the distance **L** because you can't get close to the base of the structure, use the Law of Sines as in figure c below:

Knowing $Ø_1$, $Ø_2$, and **L**. the height **h** can be calculated using the expression:

$$h = \frac{\sin Ø_1 \cdot \sin Ø_2}{\sin Ø_2 - Ø_1} L$$

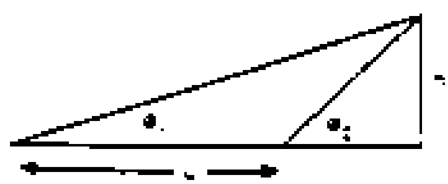
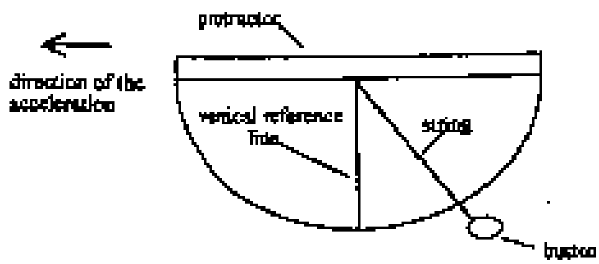


figure c

CONSTRUCTING AND USING A HORIZONTAL ACCELEROMETER

A simple, but effective, horizontal accelerometer may be constructed from a paper protractor, a piece of string, and a plastic button or small washer. Tie a button on one end of a piece of string roughly 15-20 cm long. Pass the other end of the string through the small hole found at the bottom center of most protractors. The string may be taped in place if no hole exists. The finished product should appear as follows:



When the edge of the protractor is pointed in the direction of the acceleration, the freely hanging mass (button or washer) will swing in the opposite direction (see figure). The angle formed by the string and the vertical reference line is related to the acceleration. To find your acceleration, you may use the horizontal acceleration chart in the appendix of this manual. **Note: The angle of deflection of the string and mass as indicated by the protractor reading is actually the complement of the actual angle of deflection. Before referring to the acceleration chart, you must subtract the reading on the protractor from 90 degrees.**

SEXTANT

Triangulation instrument and horizontal accelerometer

1. Cut out the sextant.

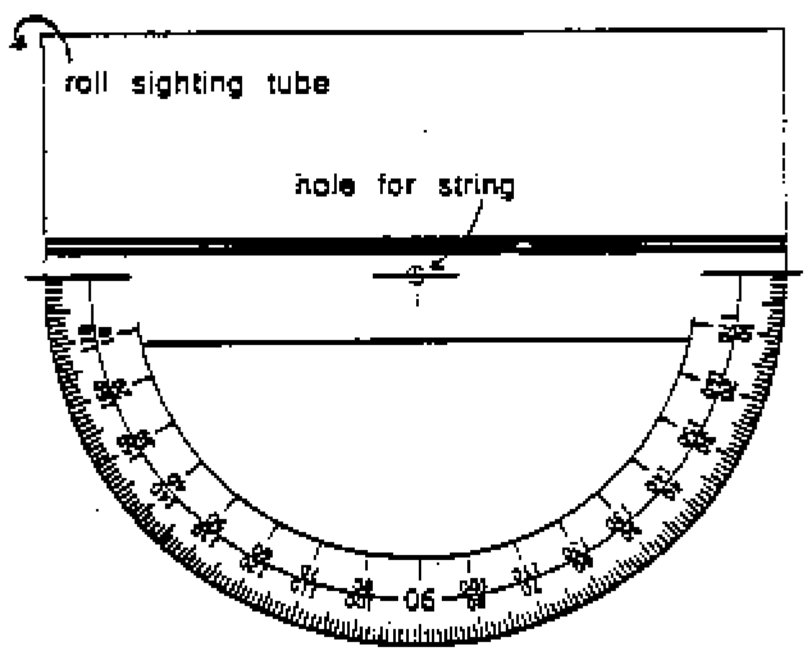
2. Fold the top section over a pencil and roll it down to the heavy double line to make a sighting tube.

3. Tape the rolled paper tube closed and then let the pencil slide out.

4. Glue the sextant to a 8" x 5" index card and trim.

5. Take about 20 cm of heavy thread and tie one end to a weight such as a rubber stopper. Tie the other end through the hole at the top of the sextant.

6. Let the thread hang free. The angle it marks off is the angular height of an object seen through the tube.

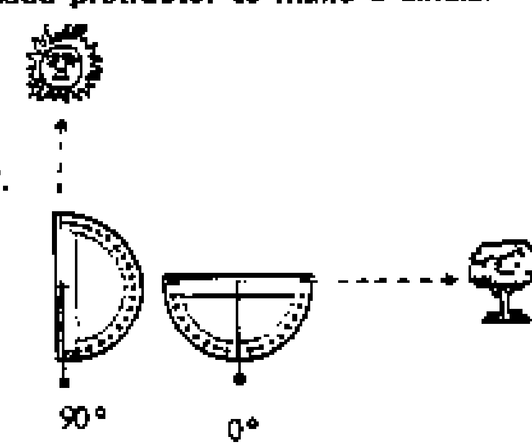


Alternatively, a drinking straw can be attached to a plastic protractor to make a similar device.

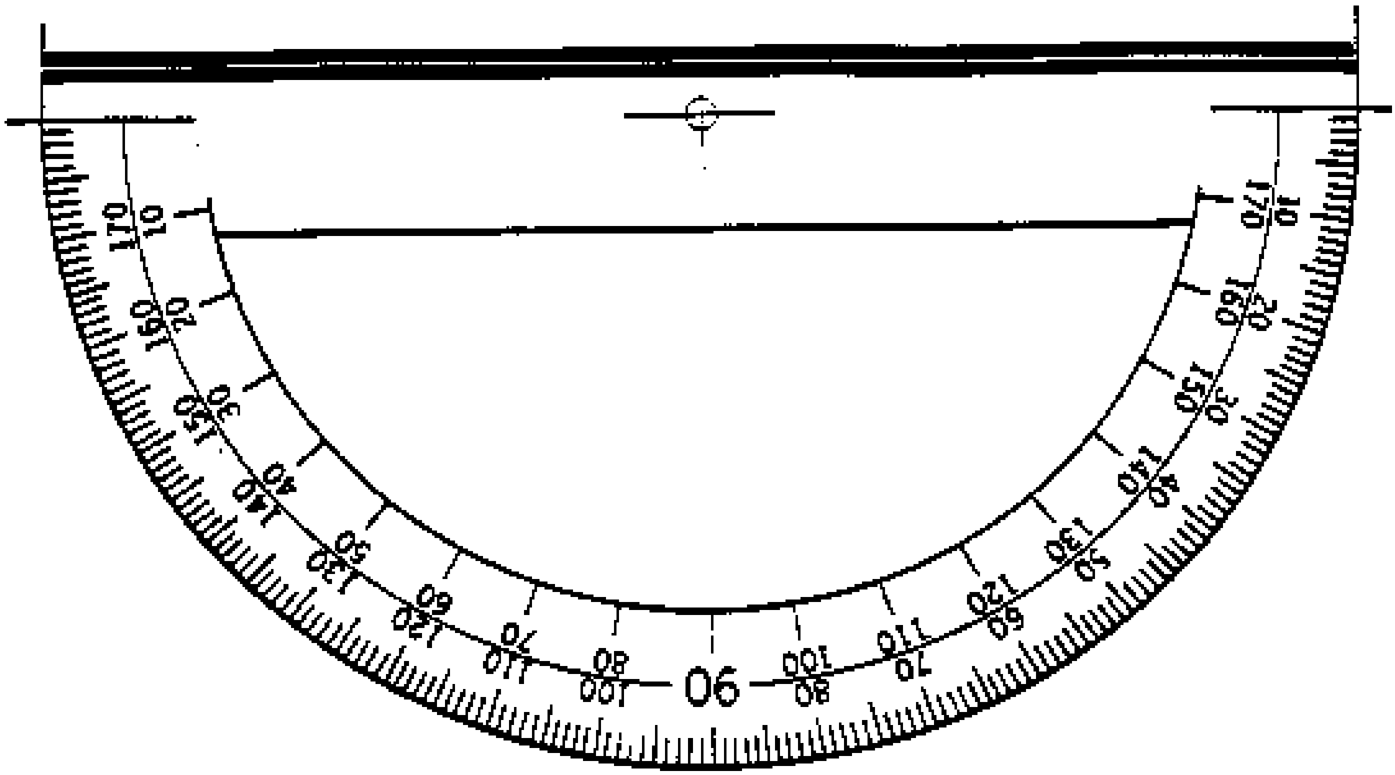
For instance:

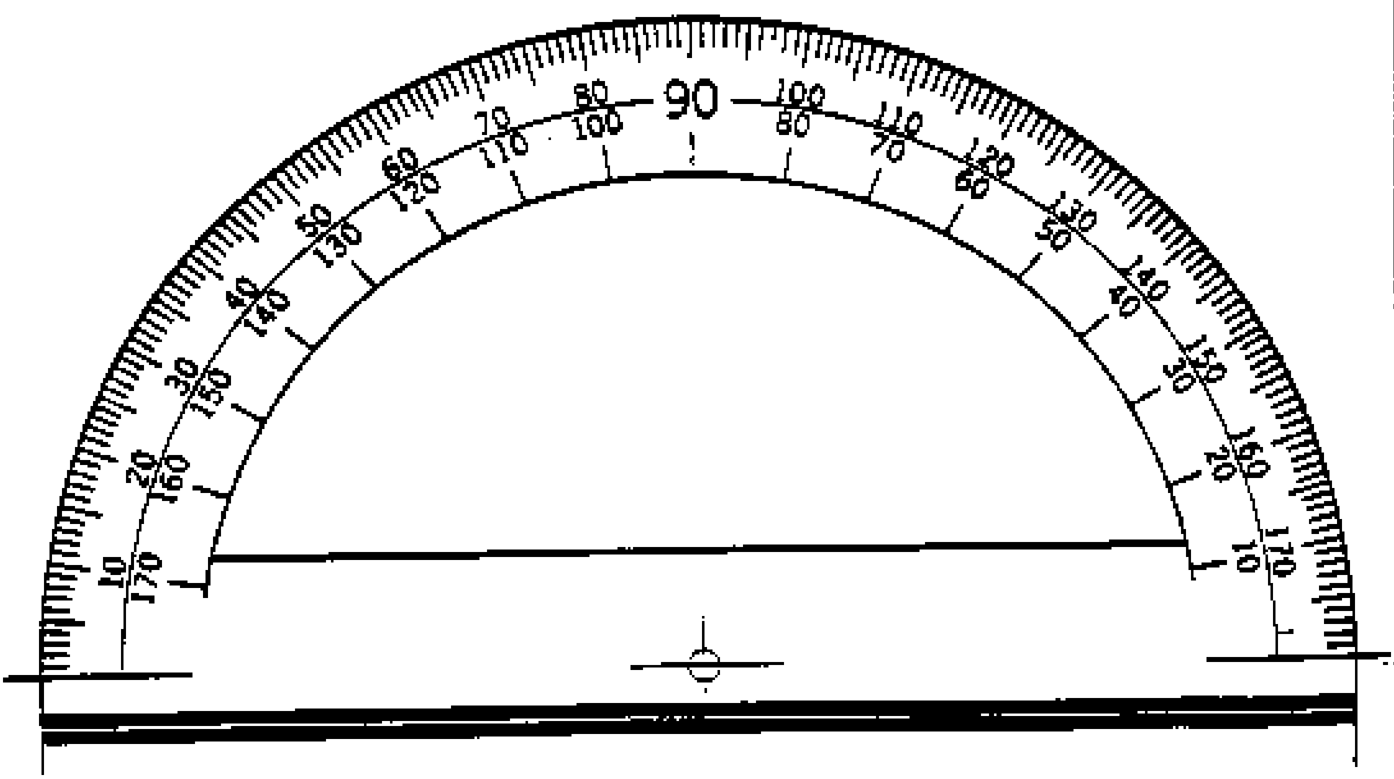
An object directly overhead has an angular height of 90°.

An object on the horizon has an angular height of 0°



SEXTANT





VERTICAL ACCELEROMETER

A very nice vertical accelerometer can be made using parts like those shown to the right. The necessary parts include are listed below with the quantities given being per accelerometer.

1. (1) rigid clear plastic tube, at least 1.3 cm inside diameter and about 30 cm long. Some thermometer cases are a suitable size. You can also obtain plastic mailing tubes in a variety of suitable sizes.

2. (2) plastic end caps or rubber stoppers

3. (1) small spring (Approximately 1.5 cm/g). If you make the multidirectional accelerometer you will need 2 of these. Rubber bands may be substituted for the springs, but have a distinct disadvantage. The force constant of the rubber bands will change if they are left under tension for very long. Consequently the calibration of the accelerometer will change with use. Springs are highly recommended.

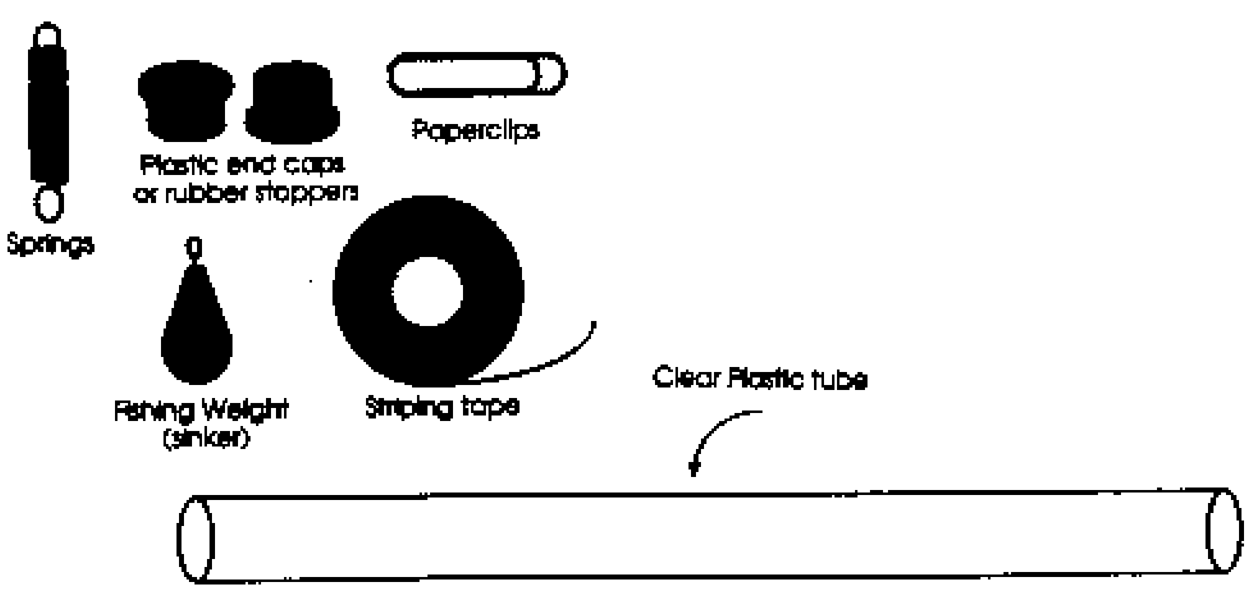
4. (1) fishing weight (sinker) with a mass of about 10 g.

5. (2) paper clips. You will need three of these if you make the multidirectional accelerometer.

6. Narrow tape, approximately 1/8" wide for marking acceleration calibrations. Vinyl automotive pinstriping tape works well. Some correction tape may also be a suitable width.

7. 1" wide tape for securing all connections.

8. 7" rubber band for a wrist strap.



CONSTRUCTING THE VERTICAL ACCELEROMETER

1. Attach the sinker to the spring and glue, tape and/or crimp the connection so that they will not detach.

2. Make two small holes through the end cap or stopper large enough to insert the ends of a paper clip.

3. Unbend a paper clip and suspend the spring/sinker combination. Push the paper clip through the holes int he end cap or stopper. Place the end cap or stopper on one end of the tube.

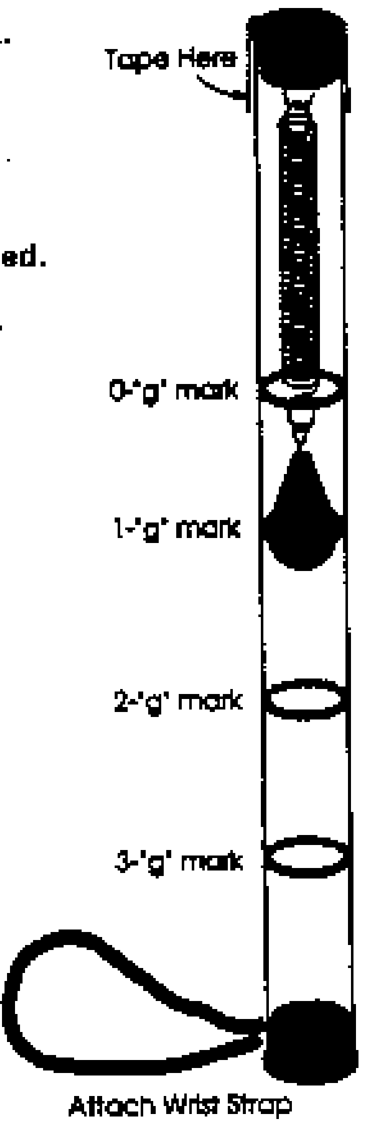
4. With the tube held horizontally, mark the position of the weight when the spring is relaxed with a ring of striping tape. This is the 0 "g" mark.

5. Hold the tube vertically with the weight hanging. Mark the position of the sinker. This is the 1" mark.

6. Assuming that the spring obeys Hooke's Law and stretches linearly, mark off position for 2 and 3 "g" the same distance away.

7. Tape the paper clip ends so that they are not exposed.

8. Insert the other end cap and attach the large rubber band as a wrist strap.



MULTIDIRECTIONAL ACCELEROMETER

The vertical accelerometer shown to the right can be easily modified so that it can be sued to measure horizontal accelerations and negative vertical accelerations. This modifications involves simply attaching a spring to the other end of the sinker and in turn attaching the second spring to the other end of the plastic tube.

1. Cut the brass loop off the sinker. Unbend a paper clip and pass it through the hole in the stopper.

2. Bend the end of the paper clip into loops at both ends of the sinker. Wrap the wire on itself several times to make a secure loop.

3. Attach a spring to each end of the sinker.

4. Attach each remaining end of a spring to an end cap or stopper at the end of the tube with paper clips as described in the vertical accelerometer direction.

5. With the tube held horizontally, mark the position of the wright. This is the 0 "g" mark. Hold the tube vertically. Mark the position of the weight. This is the 1 "g" mark. Invert the tube and mark the position of the weight. This is the negative 1 "g" mark. Other positions, 2 "g", -2 "g", 3 "g", etc. can be marked the same distances along the tube.

6. Secure the ends of the tube with tape and attach a rubber band wrist strap.